KNOWLEDGE MANAGEMENT MODEL FOR CONSTRUCTION PROJECTS

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In the past there has been no structured approach to learning from construction projects once they are completed. At present the construction industry is adapting concepts of knowledge management to improve the situation. In this paper knowledge management benefits to construction industry organizations and projects are discussed.

The main purpose of this paper is to present knowledge management model for construction projects. Paper consists of three parts. In the first part the concept of knowledge management in construction is discussed. In the second part different knowledge management models presented in scientific literature are discussed and compared as well as the new model, developed by the authors, is presented. In the third part, basing on the proposed model, the architecture of Knowledge Based Decision Support System for Construction Projects Management has been created as well as Multiply Criteria Analysis Method COPRAS application for construction decisions support have been discussed.

Keywords: *knowledge management, construction projects, knowledge based decision support system, multiply criteria analysis*

1. Introduction

In the recent times, construction projects have turned into a more complicated, dynamic and interactive scenario. Project managers are constantly required to speed-up reflective decision-makings on time. Knowledge therefore is noted to be one of the most important resources contributing towards managerial decision-making and enhancing the competitive advantage of organizations carrying out such projects [1, 2].

The construction industry is a workplace that is dominated by heuristics. Construction companies and their personnel refer to carry out their project management tasks based upon their past experiences, rather than following a textbook approach, or established analytical approaches [3]. Indeed the costs of attracting, recruiting, and retaining talented employees are expensive [4,5]. This is further complicated by the fact that in the coming years, the construction industry is expected to loose a large portion of its skilled and knowledgeable workforce. Conversely, there is no single strategy in place, to handle construction management problems that arise. One of the most effective and powerful tools for strengthening industrial and organizational competition is through systematic identification, in the best practice of knowledge utilization and distribution.

The significance of knowledge management in construction industry is proved and researched extensively in the scientific literature. Indeed, authors present different points of view to knowledge management as well as different knowledge management models. This article covers a wide range of issues, from basic definitions and fundamental concepts, to the role of information technology and different knowledge management models presented in literature.

The main purpose of this research – is to develop knowledge management model for construction projects and to use it for the knowledge based decision support system architecture.

2. The Concept of Knowledge Management

Knowledge has been described as information, which has been used and becomes a part of a person's knowledge-based experience and behavioural patterns [6,7]. Individuals have different knowledge-based capacity and experience, thus leading to different problem solving approaches and decision-making. When choosing a construction project manager, knowledge and experience are significant [8]. Project managers must therefore be capable of knowing how to use, manage, and utilize such knowledge.

Before specifying the knowledge management (KM) models, the KM concept has to be defined first. KM has however been defined in different ways in scientific literature. According to Qunitas et al. [9], KM means to manage all knowledge continuously to meet various requirements in an organization. Coleman [10] defines KM as an umbrella term for a wide variety of interdependent and interlocking functions consisting of: knowledge creation; knowledge valuation and metrics; knowledge mapping and indexing; knowledge transport, storage and distribution; and knowledge sharing. Gurteen [11] comprehensively defined KM as an emerging set of organizational design and operational principles, processes, organizational structures, applications and technologies that helps knowledge workers dramatically leverage their creativity and ability to deliver business value.

According to Robinson [12], knowledge management relates to unlocking and leveraging the different types of knowledge so that it becomes available as an organisational asset. Implementing KM enables an organisation to learn from its corporate memory, share knowledge, and identifies competencies in order to become a forward thinking and learning organization.

Other authors mentioned more KM benefits to projects management. Kamara et al. [5], Love et al. [13] state that the role of effective management of knowledge is evident in producing innovation, reducing project time, improving quality and customer satisfaction. According to Siemieniuch and Sinclair [14], through knowledge management an organisation's intangible assets can be better exploited to create value, with both internal and external knowledge being leveraged to the benefit of the organisation. In projects, knowledge management can improve communications within teams, and provide more informed knowledge by sharing best practice documents, lessons learned, project management and system engineering methodologies, examples of review packages, and the rationale for strategic decisions. Kaklauskas and Kanapeckiene [15] distinguish such KM benefits as productive information use, activity improvement, intelligence enhancement, intellectual capital storage, strategic planning, flexibility acquisition, best practice gathering, success probability enhancement and productive collaboration. Authors have used the systemized approach to KM definition (see Fig. 1).

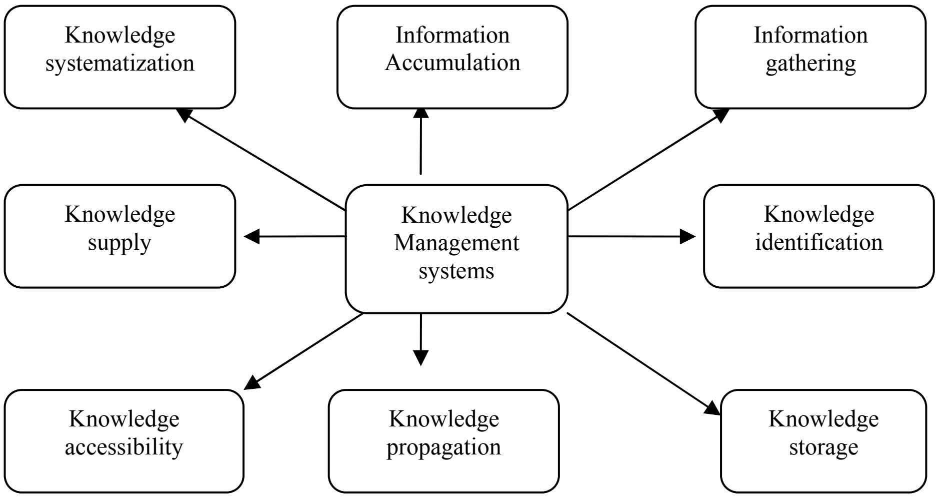


Figure 1. Functions of knowledge management systems [15]

The different definitions of KM in the literature result from the various perspectives and contexts that are specific to the authors and their research fields. Within construction, KM can be difficult to define precisely as there is not a general consensus on a single unified meaning of the concept. However, Egbu [16] explains that knowledge is an important resource for construction organisations due to its ability to provide market leverage and contributions to organisational innovations and project success. The idea of knowledge as a competitive resource within project-oriented industries is a concept shared by numerous authors: Nonaka and Takeuchi [2], Egbu [16], Egbu and Botteril [17], Oltra [18], etc.

The potential benefits of effectively utilising their knowledge has meant that an increasing number of construction companies have identified the need to implement KM initiatives. However, the difficulties associated with understanding and managing organisational knowledge has meant that organisations experience numerous problems in successfully implementing and sustaining their initiatives [16,18]. Egbu and Botteril [17] state that due to the project-oriented nature of construction organisations, cultural considerations are important for successful KM. They continue by stating that the short-term, task-focussed work can promote a culture, which inhibits continuous learning.

It can be concluded that though academics and industrial organisations have recognised the need for KM, there can be confusion over specific definitions of knowledge and KM within construction organisations. As a result there is danger that KM initiatives can become misguided and not serve their desired purpose. It is important for the whole organisation to understand what KM is and why it is important. The organisation should take a recognised and accepted generic definition, apply it to their specific context, and tailor it to accommodate specific business objectives. This will require support, agreement and communication from the top. To ensure an alignment with its business objectives and strategies, the organisation should consider the type of work they carry out, their culture, dynamics, politics and practices, as well as the added value that is required from the KM initiative [19].

Basing on these assumptions authors of this article are aiming to develop the generalized and easily adaptive KM model, which is presented further.

3. Development of the Knowledge Management Model for Construction Projects

Different KM models developed by different authors emphasizing various aspects can be found in scientific literature. Most of them are usually activity oriented. Four major dimensions for the process of KM activities presented by Nonoka and Takeuchi [2] and Davenport and Prusak [21] are usually adopted for the general models structure of KM in enterprises. These four dimensions are knowledge creation, knowledge diffusion, knowledge transfer and knowledge inventory.

Maqsood et al. [3] developed the integrated knowledge management, organisational learning and innovation model. This model explains the transformation of the organisation over time by illustrating organisational learning. It shows three transformation stages that are indicative of the transformation process, which is a continuous process: before transformation, transformation, ideal transformed state, e.g. existing knowledge of organization, knowledge after certain learning, knowledge in the organization after further learning.

Korsvold and Russak [21] in the proposed generic model distinguish three necessary arenas for knowledge development, being identified as "collective knowing", relational knowledge and knowing how. Consequently, the relationship between the three conditions or the knowledge content of the arenas for knowledge creation in constituting a generic model for creating organizational innovation in the operative accomplishment of the building process as a whole is intrinsically dynamic and interdependent. This implies a continuous process of internalisation and externalisation between tacit (embedded knowledge: the common frame of reference as Web-based communicative and reflective device in the operative accomplishment of the building process) and encultured knowledge (encultured: the common frame of reference as shared collective understanding of the building process as a whole).

It should be noticed, however, that not so much of the proposed models are adapted to construction sector.

Teerajetgul and Charoenngam [22] research addressed the concerns of practicing knowledge management in construction projects by examining the relationships between knowledge factors and the knowledge creation process composed of socialization, externalisation, combination, and internalisation. A framework was employed to test these relationships and the empirical evidence supports the relationships. Findings from this study confirmed that three selected factors (IT, incentive, and individual competency) affect the overall knowledge creation process in Thai construction projects. From the research results it can be assumed that KM in construction projects is impossible without IT and human interaction.

Tserng and Li [23] presented more detail framework of knowledge management used in construction projects. Authors distinguished three construction project's KM spheres, namely, content management, experience management and process management and six management stages:

- problem happening;
- create knowledge;
- share knowledge;
- record knowledge;
- knowledge storage;
- knowledge reused.

Also authors proposed activity based model.

The model presented by authors is developed basing on the synthesis of the above discussed models, indeed it is more concentrated on IT and construction project's life cycle as well as decision support (see Fig. 2).

The given view to KM in construction projects is generalized by distinguishing four the most important knowledge management stages: project information and knowledge gathering, knowledge acquisition, best practice knowledge data base creation and knowledge based decision support for implementation of other projects.

Project information and knowledge gathering as well as knowledge acquisition stages are strongly connected with all construction project life cycle activities, including: conceptual planning, design, procurement, construction, operation and maintenance. It should be noticed, that the information and knowledge must be gathered from the all different bodies and organizations participating in the project e.g. clients, designers, consultants, contractors, and inspectors because inter- and intra-discipline communication between these distinctive professionals is often problematic. The lack of integration and co-ordination between the industry's distinct professions can be perceived as a major contributory factor to poor project performance [24].

An effective knowledge strategy is required to acquire and manage both explicit and tacit knowledge.

Explicit knowledge is the type of knowledge that is readily available in the organisation in the form of books, procedures and can be appropriately archived for use when required. Indeed, tacit knowledge is embedded in organizational routines and processes and employees heads. It is a very complex type of knowledge. The challenge of knowledge management is to make it explicit through the balanced use of technology, and soft human-related factors like leadership, vision, strategy, reward systems and culture. Researches results revealed the importance of tacit knowledge in relation to organizational performance and achievement of competitive advantage and has further highlighted the relevance of tacit knowledge in the construction industry by considering its intrinsic characteristics [25].

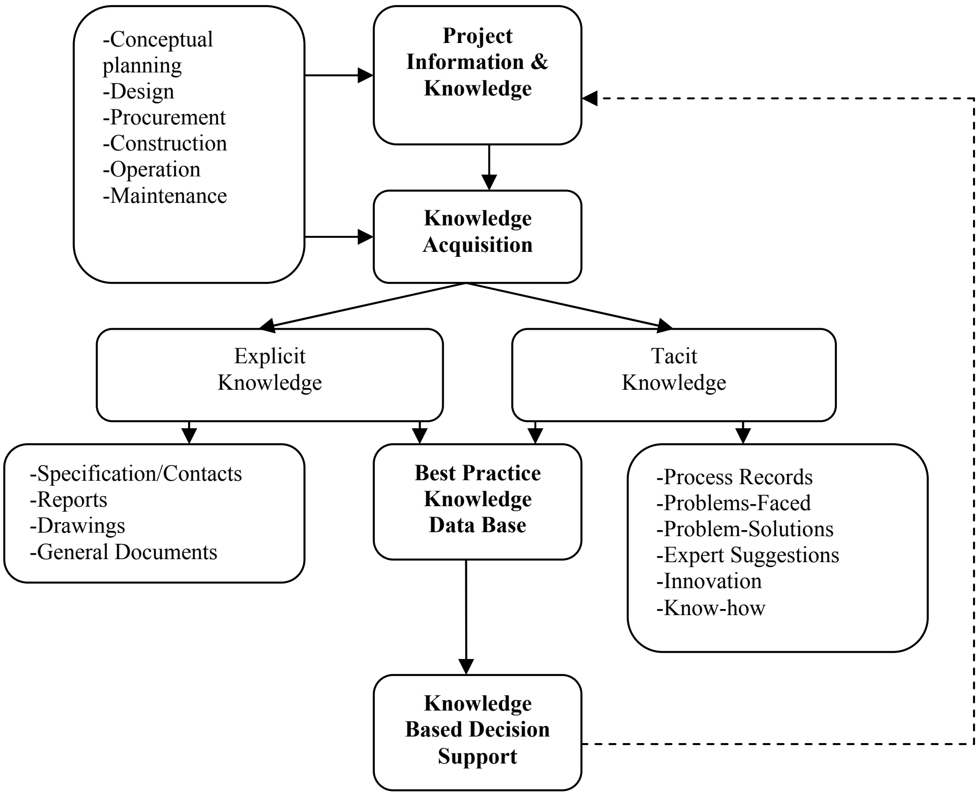


Figure 2. Knowledge management model for construction projects

Tserng and Lin [23] distinguished the main problems indicated in construction phases by acquiring and using tacit and explicit knowledge. According to authors, problems for tacit knowledge are loss of experience, loss of Know-how, problem-solution loss, loss of innovation. Problems connected with explicit information are mainly connected with information saving problems: information can be recorded incompletely or partly.

The above mentioned problems can be solved by the information technology use and tacit data coding as well as other technology based measures: videos, interviews, etc.

When the knowledge is collected the next step is the best practice data base creation avoiding insignificant or less worthy information. It should be noticed that usually construction projects are not universal. Therefore the standardisation of all project life cycle phases is needed. Furthermore the data base must be periodically updated for new information and knowledge acquisition.

When the best practice data base is created, the second step is knowledge application and reuse in order to make knowledge based decisions in construction projects. For this purpose authors propose to use computerized knowledge based decision support system, which is discussed in the next chapter.

4. Knowledge Based Decision Support System for Construction Projects Management

Basing on the above discussed knowledge management model for construction projects, the architecture of computerized Knowledge Based Decision Support System for Construction Projects (DSS-CP) can be created (see Figure 3).

DSS-CP consists of a database, database management system, model-base, model-base management system and a user interface.

The DSS-CP database management system allows users to: present information of the general physical and functional state of the building process; present information of the physical state of the building's envelope; calculate the volume of work to be carried out; rationalize the energy consumption of the building; propose the required measures to increase the quality of air and indoor environment and analyse the construction processes scenarios by taking into account the system of criteria.

A module base allows the DSS-CP's user to select the most suitable construction alternatives by comparing the measures that promote the greatest value to all interested bodies and organizations.

The following models of a model-base aim at performing the functions of: a model for developing the alternative variants of a building's enclosures, a model for determining the initial weight of the criteria (with the use of expert methods), a model for the establishment of the criteria weight, a model for the multi-variant design of a building construction alternatives, a model for multiple criteria analysis and for setting the priorities, a model for the determination of a project's utility degree and market value, a model for negotiations.

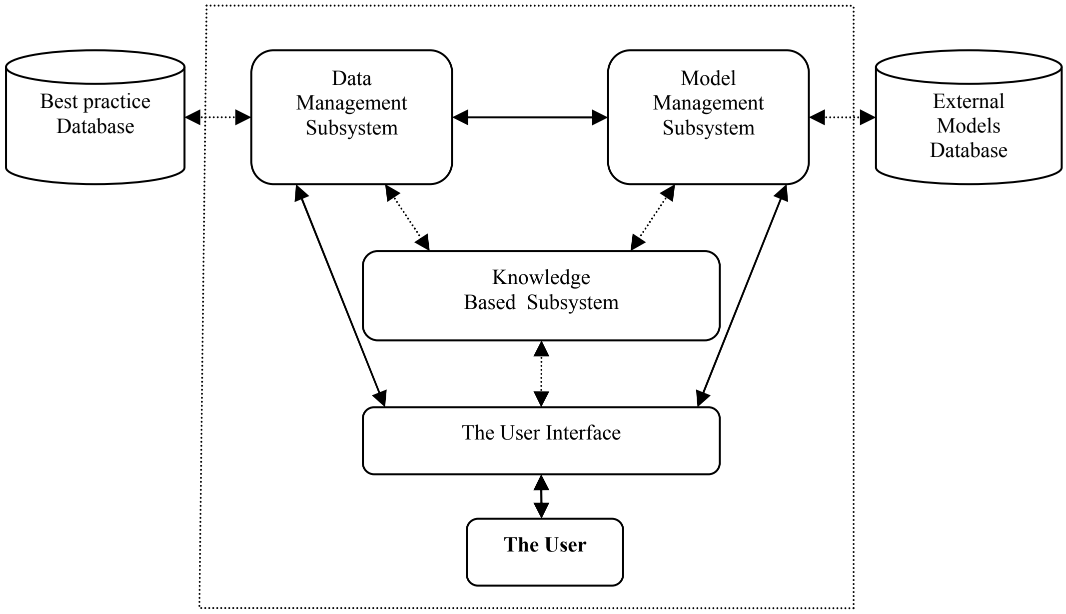


Figure 3. Architecture of Knowledge Based Decision Support System for Construction Projects (DSS-CP)

The best construction alternatives selection in the presented DSS-CP is based on the Complex Proportional Assessment method (COPRAS) [26, 27].

This method assumes direct and proportional dependence of significance and priority of investigated versions on a system of criteria adequately describing the alternatives and on values and significances of the criteria. The system of criteria is determined and the values and initial significances of criteria are calculated by experts. All this information can be corrected by interested parties (customer, users, etc.) taking into consideration their pursued goals and existing capabilities. Hence, the assessment results of alternatives fully reflect the initial refurbishment data jointly submitted by experts and interested parties.

The determination of significance and priority of alternatives is carried out in four stages.

Stage 1: The weighted normalized decision making matrix D is formed. The purpose of this stage is to receive dimensionless weighted values from the comparative indexes. When the dimensionless values of the indexes are known, all criteria, originally having different dimensions, can be compared. The following formula is used for this purpose:

$$d_{ij} = \frac{x_{ij} \cdot q_i}{\sum_{j=1}^{n} x_{ij}}, \quad i = \overline{1,m}; \quad j = \overline{1,n}, \tag{1}$$

where x_{ij} - the value of the i-th criterion in the j-th alternative of a solution; m - the number of criteria; n - the number of the alternatives compared; q_i - significance of i-th criterion.

The sum of dimensionless weighted index values d_{ij} of each criterion x_i is always equal to the significance q_i of this criterion:

$$q_i = \sum_{j=1}^{n} d_{ij}, \quad i = \overline{1,m}; j = \overline{1, n}.. \tag{2}$$

In other words, the value of significance q_i of the investigated criterion is proportionally distributed among all alternative versions a_j according to their values x_{ij}.

Stage 2: The sums of weighted normalized indexes describing the j-th version are calculated. The versions are described by minimizing indexes S_{-j} and maximizing indexes S_{+j}. The lower value of minimizing indexes is better and the greater value of maximizing indexes is better. The sums are calculated according to the formula:

$$S_{+j} = \sum_{i=1}^{m} d_{+ij}; \quad S_{-j} = \sum_{i=1}^{m} d_{-ij}, \quad i = \overline{1,m}; j = \overline{1, n}.. \tag{3}$$

In this case, the values S_{+j} (the greater is this value (project "pluses"), the more satisfied are the interested parties) and S_{-j} (the lower is this value (project "minuses"), the better is goal attainment by the interested parties) express the degree of goals attained by the interested parties in each alternative project. In any case the sums of "pluses" S_{+j} and "minuses" S_{-j} of all alternative alternatives are always respectively equal to all sums of significances of maximizing and minimizing criteria:

$$S_{+} = \sum_{j=1}^{n} S_{+j} = \sum_{i=1}^{m}\sum_{j=1}^{n} d_{+ij},$$
$$S_{-} = \sum_{j=1}^{n} S_{-j} = \sum_{i=1}^{m}\sum_{j=1}^{n} d_{-ij}, \quad i=\overline{1,m};\ j=\overline{1,n} \tag{4}$$

Stage 3: The significance (efficiency) of comparative versions is determined on the basis of describing positive alternatives ("pluses") and negative alternatives ("minuses") characteristics. Relative significance Q_j of each alternative a_j is found according to the formula:

$$Q_j = S_{+j} + \frac{S_{-\min} \cdot \sum_{j=1}^{n} S_{-j}}{S_{-j} \cdot \sum_{j=1}^{n} \frac{S_{-\min}}{S_{-j}}}, \quad j=\overline{1,n}. \tag{5}$$

Stage 4: Priority determination of alternatives. The greater is the Q_j the higher is the efficiency (priority) of the refurbishment alternative.

The analysis of the method presented makes it possible to state that it may be easily applied to evaluating the projects and selecting most efficient of them, being fully aware of a physical meaning of the process. Moreover, it allowed formulating a reduced criterion Q_j which is directly proportional to the relative effect of the compared criteria values x_{ij} and significances q_i on the end result.

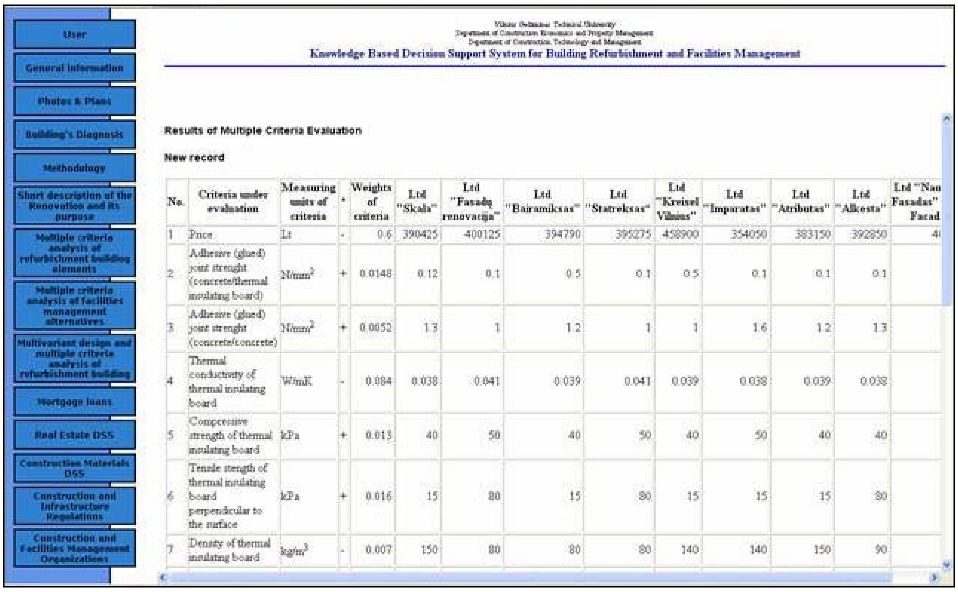
Significance Q_j of project a_j indicates satisfaction degree of demands and goals pursued by the interested parties - the greater is the Q_j the higher is the efficiency of the project.

The degree of project utility is directly associated with quantitative and conceptual information related to it. If one project is characterized by the best comfort ability, aesthetics, price indices, while the other shows better maintenance and facilities management characteristics, both having obtained the same significance values as a result of multiple criteria evaluation, this means that their utility degree is also the same. With the increase (decrease) of the significance of project analysed, its degree of utility also increases (decreases). The degree of project utility is determined by comparing the project analysed with the most efficient project. In this case, all the utility degree values related to the project analysed will be ranged from 0% to 100%. This will facilitate visual assessment of project efficiency.

The formula used for the calculation of alternative a_j utility degree N_j is given below:

$$N_j = \left(Q_j : Q_{max}\right) \cdot 100\%. \tag{6}$$

Previously discussed DSS-CP architecture concept has been used for Knowledge Based Decision Support System for Buildings Refurbishment, developed in Vilnius Gediminas Technical University by Zavadskas and Kaklauskas (see the fragment on Fig. 4) [6, 15, 28].



No.	Criteria under evaluation	Measuring units of criteria	*	Weights of criteria	Ltd "Skala"	Ltd "Fasadų renovacija"	Ltd "Bairamiksas"	Ltd "Statreksas"	Ltd "Kreisel Vilnius"	Ltd "Imparatas"	Ltd "Atributas"	Ltd "Alkesta"	Ltd "Nau Fasadas" Facad
1	Price	Lt	-	0.6	390425	400125	394790	395275	458900	354050	383150	392850	4(
2	Adhesive (glued) joint strenght (concrete/thermal insulating board)	N/mm²	+	0.0148	0.12	0.1	0.5	0.1	0.5	0.1	0.1	0.1	
3	Adhesive (glued) joint strenght (concrete/concrete)	N/mm²	+	0.0052	1.3	1	1.2	1	1	1.6	1.2	1.3	
4	Thermal conductivity of thermal insulating board	W/mK	-	0.084	0.038	0.041	0.039	0.041	0.039	0.038	0.039	0.038	
5	Compressive strength of thermal insulating board	kPa	+	0.013	40	50	40	50	40	50	40	40	
6	Tensile strength of thermal insulating board perpendicular to the surface	kPa	+	0.016	15	80	15	80	15	15	15	80	
7	Density of thermal insulating board	kg/m³	-	0.007	150	80	80	80	140	140	150	90	

Figure 4. The fragment of Knowledge Based Decision Support System for Buildings Refurbishment

The presented system can make up to 100,000 building refurbishment alternative versions, perform their multiple criteria analysis, determine the utility degree, market value and select the most beneficial alternative without human interference.

Basing oneself on the collected information and the BR-DSS it is possible to perform a multiple criteria analysis of the refurbishment project's components (walls, windows, roof, floors, volumetric planning and engineering services, etc.) and select the most efficient versions. After this, the received compatible and rational components of a refurbishment are joined into the projects. Having performed a multiple criteria analysis of the projects in this way, one can select the most efficient projects [15].

Authors believe that these advantages can be achieved also in management of the construction projects of other types.

Conclusions

Knowledge management is the key factor of the successful implementation of construction projects and tasks achievement of interested bodies as well as organizations. Indeed there is no universal concept of knowledge management in construction. It must be developed by each organization individually.

In order to systemize knowledge management for construction projects, authors developed the model consisting by four main stages: project information and knowledge gathering, knowledge acquisition, best practice knowledge data base creation and knowledge based decision support for other projects implementation. Model shows the integrated view to construction projects life-cycle as well as IT usage. Basing on this knowledge management model for construction projects, the architecture of computerized Knowledge Based Decision Support System for Construction Projects (DSS-CP) has been created.

The presented concept has been already used to create Knowledge Based Decision Support System for Refurbishment projects. The system is based on Multiply Criteria Analysis in applying COPRAS method. Authors believe that system's advantages can be achieved in management of other type's construction projects.

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